# Economic assessment of traffic noise in planning

- Danish experiences

Danish Road Institute
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# Economic assessment of traffic noise in planning

- Danish experiences

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# Contents

# Abstract

In Denmark there is increasing focus on maximizing the socio-economic benefit of environmental investments. The Road Directorate has a long tradition for developing and using cost-benefit evaluation methods, which include external costs such as noise, and recently the Ministry of Transport has published guidelines on how to carry out such evaluations. These methods and guidelines will be presented as a basis for presenting actual assessments. In 2003, a working group with members from six ministries published a suggestion for a strategy to reduce road traffic noise, which focuses on the cost-effectiveness of various means of noise abatement. These means include barriers, various types of pavements, less noisy vehicles and planning initiatives such as reduced speed. In 2004 the Danish Road Institute did a technical and socio-economic evaluation of using various pavements – including noise reducing pavements – on an enlargement of the Motorring 3 in Copenhagen. The initial Danish results of analyses of cost benefit assessments presented in this paper were carried out in a co-operation with the Danish (DRI) and Dutch (DWW) road institutes. The two institutes have signed a contract called the DRI-DWW noise abatement program. This is part of the large Dutch Innovation Program on Noise, also called the IPG research program.

# Preface

This report contains an article written by Lars Ellebjerg Larsen and Hans Bendtsen for Forum Acusticum 2005 in Budapest.

# 1. Introduction

In Denmark, as in many other countries, there is increasing focus on the need to reduce noise from road traffic, and also on maximizing the socio-economic benefit of environmental investments.

The combination of these focus points has lead to cost-benefit assessments (CBA) of noise abatement, which are of broader interest. Also the Danish assessment method in itself may be of broader interest, as it through the use of the Noise Exposure Factor (NEF – Støjbelastningstal SBT) takes into account differences between various means of abatement, which make direct comparisons of dB-reductions somewhat misleading.

The two actual CBAs presented are:
1. A comparison of various means of abatement, including 2-layer porous asphalt and thin layer noise reducing asphalt concrete layers. The comparison is part of the work on a national strategy for limiting road traffic noise [1].
2. An evaluation of the use of two different noise reducing pavements, 1-layer porous asphalt and thin layer noise reducing asphalt concrete layers, on the Motorring 3 (M3) in Copenhagen [2].

The socio-economic assessment of pavements as means of noise abatement is part of a co-operation between the Danish (DRI) and Dutch (DWW) road institutes called the DRI-DWW noise abatement program [16]. A total of seven projects are carried out inside the framework of the program, which is part of the large Dutch Innovation Program on Noise, called the IPG research program [17]. This paper presents the initial Danish results of the project.

# 2. The Danish basis for CBA

The Danish Road Directorate (DRD) has a long tradition for developing and using cost-benefit evaluation methods, which include external costs such as noise, air pollution and barrier effect [3, 4].

The principles of the DRD methods have been included in guidelines from the Ministry of Finance [5], and recently the Ministry of Transport has published updated guidelines on how to carry out such evaluations [6].

The assessment of noise is based on annoyance at dwellings. Noise at occupational buildings and institutions is not included. Noise levels below 55 dB(A) ($L_{Aeq,24h}$, free field values at the facade) are not included and there is no differentiation between day and night time noise. These matters are all mentioned by the Ministry of Transport as possible themes for future development of the method. A common basis for the evaluation methods has been the Noise Exposure Factor (NEF), which is an expression of the accumulated noise load on the dwellings in an area.

# 3. The Noise Exposure Factor

The Noise Exposure Factor, first presented in 1989 in a guideline from the Road Directorate [7], is the basis of all Danish cost-benefit analyses of noise from road and rail traffic. It is calculated as the sum of the weighted noise loads on the individual dwellings in an area, so that dwellings with high noise levels weigh more than dwellings with less noise.

## 3.1 Calculating the NEF

The NEF is based on noise in three situations: inside the dwelling, outside the dwelling, and on outdoor areas in connection to the dwelling. The noise level outside the dwelling is calculated as free-field values on the facade and can be interpreted as the noise level to which the inhabitants are subjected when opening windows. The weight assigned to each of these situations depends on whether it is an ordinary dwelling or a weekend cottage. The weights can be seen in Table 1.

*Table 1. Weights assigned when calculating the NEF [7].*

| | Outside dwelling | Outdoor areas | Inside dwelling |
|---|---|---|---|
| Ordinary dwelling | .2 | .2 | .6 |
| Weekend cottage etc. | .1 | .3 | .1 |

The NEF is based on a dose-response relationship given by:

$$\text{Annoyance factor} = .01 * 4.22^{.1(L_{Aeq}-K)} \quad (1)$$

where

K = 16 and $L_{Aeq} \geq 30$ dB inside dwellings
K = 41 and $L_{Aeq} \geq 55$ dB outside ordinary dwellings
K = 36 and $L_{Aeq} \geq 50$ dB outside weekend cottages etc.

In practical use the mapping is often done using only noise levels outside the dwelling and assigning these the weight 1.0. This is usually a reasonable approach, as the noise level on the facade of the dwelling often is comparable to that on the outdoor areas, and because a typical facade of an ordinary Danish dwelling has a sound insulating effect of approximately 25 dB, so that the 55 dB outside on the facade and the 30 dB indoors correspond.

The number of dwellings subjected to noise in each of the three situations are counted in intervals of 5 dB and multiplied by the corresponding annoyance factor, which is shown in Table 2.

The resulting values are summed and multiplied by the corresponding weight from Table 1 to give the NEF for the situation for the type of dwelling. Finally the total NEF is calculated by adding the values for each situation and each type of dwelling. If the simple approach with using only levels outside dwellings is used, a reduction of 1 in NEF approximately equals:

- shifting 9 dwellings from 55-60 dB to below 55 dB or from 60-65 dB to 55-60 dB.
- shifting 4 dwellings from 65-70 dB to 60-65 dB.
- shifting 2 dwellings from 70-75 dB to 65-70 dB.
- shifting 1 dwelling from 75-80 dB to 70-75 dB.

*Table 2. Annoyance factor for the individual dwellings [7].*

| Noise level $L_{Aeq}$ | Type of area | | | |
|---|---|---|---|---|
| | Ordinary dwelling | | Weekend cottages etc. | |
| | Indoors | Outside | Indoors | Outside |
| 30-35 | .11 | - | .11 | - |
| 35-40 | .22 | - | .22 | - |
| 40-45 | .45 | - | .45 | - |
| 45-50 | .93 | - | .93 | - |
| 50-55 | 1.92 | - | 1.92 | .11 |
| 55-60 | 3.94 | .11 | 3.94 | .22 |
| 60-65 | - | .22 | - | .45 |
| 65-70 | - | .45 | - | .93 |
| 70-75 | - | .93 | - | 1.92 |
| 75-80 | - | 1.92 | - | 3.94 |

## 3.2 Why use the NEF?

Why use the NEF instead of simply counting the number of dwellings in the dB-intervals? In relation to CBA, it is an advantage that the NEF-method produces a measure of the noise load, which is given by a single figure. This makes it easy to calculate the noise-costs of a scenario by simply multiplying by the NEF unit-value.

It is also an important advantage that the NEF takes into account the differences in where and how various means of abatement reduce noise levels. Noise reducing pavements reduce equally everywhere, whereas noise barriers have greatest effect at ground level and facade insulation only reduces noise levels indoors with closed windows. These differences make it difficult to compare dB-reductions directly.

## 3.3 Future development of the NEF

The NEF-method was developed at a time when computers were not as common and powerful a tool for planning as today. This is reflected in the counting of dwellings within 5 dB intervals. A result of the use of these intervals is that even small reductions in noise levels may lead to large reductions in the NEF. In other cases reductions of up to 4 dB may not reduce NEF at all.

If for instance predictions show that the noise level at a great number of dwellings is reduced from 64.5 to 64.4 dB, and the levels are rounded up or down to whole numbers, the dwellings are placed in different intervals in the two scenarios. This leads to the annoyance factor being double in one scenario compared to the other. This could be amended by using smaller intervals or even continuous values for the annoyance factor.

Another point of possible development of the method is the annoyance function and the various weights assigned to the different situations. The function is based on a Danish survey from the late 1970s, and both opinions on road traffic noise and knowledge on noise annoyance has changed since then and since the development of the method in the late 1980s.

Figure 1 compares the NEF annoyance function with three more recent relationships. The NEF function seems to underestimate the annoyance at low noise levels and overestimate it at high levels.

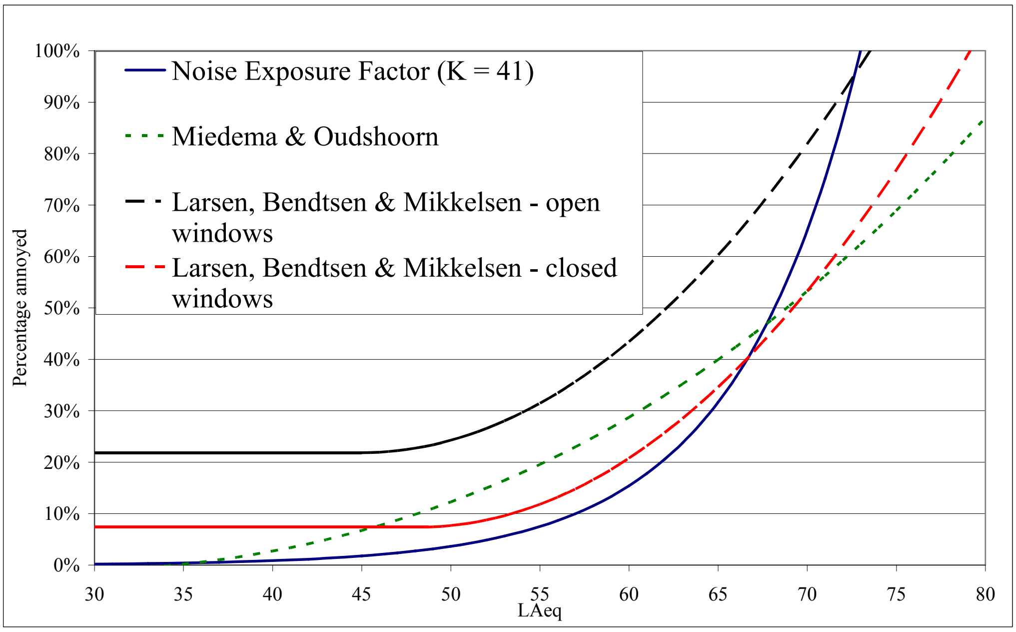


*Figure 1. Comparison of dose-response relationships [7, 8, 9].*

It may also be considered incorporating other factors of influence on the annoyance, for instance a function relating to whether or not the dwelling has a quiet side. This has been shown to significantly influence the level of annoyance [10].

# 4. Strategy for reducing noise from road traffic

In 2003, the Danish Ministries of the Environment, Finance, Transport, the Interior and Health, Justice and Economic and Business Affairs published a proposal for a strategy to reduce noise from road traffic [1]. In preparation of the proposal, reports were drawn up on annoyance and health effects of road traffic noise and on means of abatement and socio-economic evaluation [11, 12, 13].

## 4.1 Health effects and costs to society

The assessment of health effects in [11] is based on a study of the international literature on the subject. It is concluded that the documentation of actual health effects of noise from road traffic is weak and without clear evidence, and the estimates of costs are therefore done with reservation.

There is some evidence of a connection between noise and ischaemic heart disease, although the risk factors related to it are uncertain. A risk factor of 1.09 per 5 dB increase in noise levels is adopted, and it is decided also to use this factor for hypertension. Other possible health effects are left out of the assessment of costs.

The assessment of costs is based on the cost-of-illness model. This leads to a conclusion that the direct costs to the health sector are 9.4 (5.5-13.5) million € per year. If all costs, including early deaths, sick leave etc., are included the estimated costs are 80 (40-120) or 456 (242-685) million € per year depending on whether estimates of loss of production through lost life are based on costs or willingness-to-pay. As the general Danish guidelines are to use willingness-to-pay when possible [5], the higher estimate of health related costs is selected for the socio-economic assessment of the various means of abatement.

The costs related to annoyance are by the hedonic method (house prices) estimated to 711 million € per year. The annoyance and health costs per NEF per year can be seen in Table 3. The house price study shows that for houses exposed to noise levels above 55 dB, the prices are reduced by 1.2 % per dB for houses near "ordinary" roads and by 1.6 % per dB for houses by motorways. If also houses exposed to noise lower than 55 dB are included, the effects on prices are .9 % and 1.5 % respectively [12].

*Table 3. Socio-economic unit value of noise from road traffic (2002 price level) [11].*

| | € per NEF per year |
|---|---|
| Annoyance | 4,440 |
| Health | 2,850 |
| Total | 7,290 |

Prior to the study for the noise strategy, the unit costs per NEF were 4,750 and 2,375 € for annoyance and health (2001 price level) with a total of 7,125 €. This cost of annoyance is an update of an older hedonic study, and the cost of health effects is fixed as 50 % of the annoyance cost. The old and the new unit costs are quite similar, so differences in results of studies done with the old and the new unit costs should be minimal.

## 4.2 Means of abatement

The socio-economic assessment of means of abatement is carried out for the means in Table 4, which shows the annual net-benefit in 2020 of implementing the means. The year 2020 is chosen because it is the earliest that the full effect of a regulation of vehicles' noise emissions and less noisy tires can be seen.

The actual extent in km of road or number of dwellings of widespread, moderate and limited use of the means in Table 4 varies depending on the applicability of the means. For an exact extent please refer to [13].

*Table 4. Socio-economic net-result of various means of abatement in 2020 [13].*

| Means of abatement | NEF reduction | Mill. € per year |
|---|---|---|
| Regulation of vehicles' noise emissions | 23,300 | 98 |
| Promote use of less noisy tires | 19,100 | 43 |
| 2-layer porous pavements | | |
| Widespread use | 53,100 | 253 |
| Moderate use | 33,900 | 219 |
| Limited use | 22,100 | 151 |
| Thin layer noise reducing pavements | | |
| Widespread use | 29,200 | 208 |
| Moderate use | 19,000 | 137 |
| Limited use | 12,600 | 91 |
| Speed reduction | | |
| Widespread use | 22,100 | -44 |
| Limited use | 15,600 | 40 |
| Noise barriers | | |
| 3 m – widespread use | 9,700 | -76 |
| 3 m – limited use | 6,700 | 15 |
| 4 m – widespread use | 10,600 | -102 |
| 4 m – limited use | 7,300 | 12 |
| Facade insulation | | |
| Widespread use | 50,900 | 165 |
| Moderate use | 12,300 | 46 |
| Limited use | 2,200 | 8.5 |

Besides the means in Table 4, the report covers ban on heavy vehicles in certain zones at night, transfer of traffic to main roads and change in the use of buildings. These means are not included in the socio-economic assessment, as this has not been possible within the scope of the project.

The use of 2-layer porous pavements and thin layer noise reducing pavements has been assessed for the same road sections, so the socio-economic effects of these means are directly comparable.

Table 4 shows the 2-layer porous pavement to have a considerably higher annual net-value than the thin layer noise reducing pavements in spite of the fact that the construction and operating costs related to porous pavements are considerably higher than those related to thin layer noise reducing pavements. For thin layer pavements the construction costs are estimated to be 15 percent higher than those of dense asphalt concrete pavements. All operating costs are estimated to be the same for thin layer and dense asphalt concrete pavements.

Compared to this, 2-layer porous pavements involve considerable extra costs for construction, cleaning and winter maintenance, and a shorter expected lifetime (7.5 vs. 15 years) of the top layer. No costs or benefits from positive or negative effects on traffic are included in the analysis. The costs of porous asphalt used in [13] are originally from [14, 15].

The expected noise reducing potentials of the two pavements are 3, 4 and 5 dB for the porous pavement and 1.5, 2 and 2 dB for the thin layer noise reducing pavements at 50, 70 and 110 km/h respectively, compared with dense asphalt concrete.

As it is the case for the noise reducing pavements, facade insulation yields higher values with increasing use, whereas barriers and speed reductions are only cost-effective as means of abatement if the use is limited to the most noise exposed and best suited locations.

# 5. The M3 analysis

In connection with an extension of the M3 in Copenhagen from four to six lanes, the DRI has analyzed technical and socio-economic aspects of using thin layer noise reducing pavements and one-layer porous asphalt [2]. Two-layer porous asphalt was not included in the analysis.

The use of noise reducing pavements is considered as a supplement to the already planed extension project, which includes a considerable utilization of barriers. However, as the choice of pavement does not influence these parts of the project, the analysis of the pavements can be considered separately.

The thin layer noise reducing pavement is expected to reduce noise by 2 dB compared to dense asphalt concrete, and for the porous pavement a 3 dB reduction is expected. This corresponds to reductions in NEF along the M3 of 184 and 272 respectively. The lifetimes of the pavements are expected to be 12 years for the thin layers and 9 years for the porous pavement, compared to 15 years for dense asphalt concrete.

The construction costs of thin layers are approximately ten percent higher than for ordinary dense asphalt concrete pavements; those for porous pavements are approximately thirty percent higher. Increases in delays to traffic due to pavement changes are included for both pavements, and in spite of considerably higher costs for winter maintenance, the use of porous pavements are expected to result in reduced service to traffic due to snow and freezing rain.

The result of the socio-economic analysis based on a 30-year period can be seen in Table 5. The analysis is based on the noise costs used prior to the survey done in relation to the noise strategy.

It is considered in the analysis that the noise reduction of the thin layer pavements may only be 1 dB, and that the reduction of the porous pavements may be as high as 4 dB. In this case the ΔNEF are 107 and 308, and the net present values (NPV) are 4.11 and 9.33 million Euros.

The M3 analysis shows the thin layer noise reducing pavement to have a higher expected NPV than porous pavement, but also that this may change if the thin layer pavement reduces noise slightly less than expected and the porous pavement reduces it slightly more.

*Table 5. Net present value for thin layer noise reducing pavements and porous pavements in the M3 analysis [2].*

| **Present value**<br>**Mill. € (2002)** | **Thin layer noise reducing pavements** | **Porous pavements** |
|---|---|---|
| Construction costs | -0.50 | -2.03 |
| Service costs | -2.54 | -12.72 |
| Remaining value | 0.55 | 0.91 |
| Delays to traffic | -4.81 | -9.62 |
| Noise benefit | 19.60 | 29.00 |
| Net present value | 12.31 | 5.50 |

# 6. Discussion

It is remarkable that the CBA for the noise strategy shows the expensive two-layer porous asphalt to be more cost-effective than thin layer noise reducing pavements, whereas the M3 analysis shows thin layer noise reducing pavements to be more cost-effective than one-layer porous asphalt.

There are several differences in the use of costs and benefits in the two analyzes, all related to the porous pavements. The most important factors are the in- or exclusion of delays to traffic, and the expected extra costs for winter maintenance.

These differences in costs related to using porous pavements may be explained by the basis on which the two analyses are done. The figures for the noise strategy are based on estimates from [14]. These estimates are based on experiences with the use of porous asphalt on an urban road with 50 km/h and some collection of international experiences. On the urban road no extra winter maintenance has been necessary, and consequently there have been no delays to traffic. In the CBA, use of 50 % extra salt is included based on international experiences.

The figures in the M3 survey are based on a more thorough collection of international experiences on winter maintenance of porous pavements on motorways. These show that besides extra salt it is necessary to establish extra warning systems for the maintenance, supplement with extra equipment and establish separate traffic guidance systems. And even with all these initiatives, delays to traffic are still to be expected. As the M3 is a heavily trafficked, often congested road, negative effects on traffic flow will count heavily in cost benefit analyzes.

The differences in included costs may account for the contradictory results in these two surveys. On the M3 impediments to the traffic are critical and will inevitably reduce the flow, whereas on many other roads, where noise reducing pavements may be relevant to use, this is not equally critical and alternative routes will often be available.

The work in the ongoing CBA project of the DRI-DWW noise abatement program will look further into the cost-effectiveness of noise reducing pavements and will also include Dutch analyses.

# 7. Acknowledgements

The project on socio-economic assessment of road traffic noise, which is part of the DRI-DWW noise abatement program, has only been made possible by the support and cooperation of the Road and Hydraulic Engineering Institute in the Netherlands (DWW) inside the framework of the Dutch IPG program.

# References

[1] '*Forslag til strategi for begrænsning af vejtrafikstøj*', Ministries of the Environment, Finance, Transport, the Interior and Health, Justice and Economic and Business Affairs, Copenhagen (2003).

[2] C.B. Nielsen, '*Støjdæmpende vejbelægninger på Motorring 3. Teknisk og samfundsøkonomisk analyse*', External note 19 2004, Danish Road Directorate – Danish Road Institute, Roskilde (2004).

[3] '*Undersøgelse af større hovedlandevejsarbejder. Metode for effektberegninger og økonomisk vurdering*', Danish Road Directorate, Copenhagen, ISBN-87-7491-383-3 (1992).

[4] '*The Danish Highway Investment Evaluation Model*', Danish Road Directorate, Copenhagen, ISBN-87-7491-431-6 (1992).

[5] '*Vejledning i udarbejdelse af samfundsøkonomiske konsekvensvurderinger*', Ministry of Finance, Copenhagen, ISBN-87-7856-308-9 (1999).

[6] '*Manual for samfundsøkonomisk analyse – anvendt metode og praksis på transportområdet*', Ministry of Transport, Copenhagen, ISBN-87-91013-36-4 (2003).

[7] '*Støjhensyn ved nye vejanlæg*', Danish Road Directorate, Copenhagen, ISBN-87-7491-304-2 (1989).

[8] H.M.E. Miedema and C.G.M. Oudshoorn, '*Elements for a position paper on relationships between transportation noise and annoyance*', Miedema H.M.E. and Oudshoorn C.G.M., TNO report, TNO Prevention and Health, Leiden (2000).

[9] L.E. Larsen, H. Bendtsen and B. Mikkelsen, '*Traffic noise annoyance. A survey in Aarhus, Odense and Randers*', Report no. 5, Danish Transport Research Institute, Lyngby, ISBN-87-7327-080-6 (2002).

[10] E. Öhrström and A. Skånberg, 'Annoyance and activity disturbances caused by road traffic noise – field studies on the influence of access to quietness', *Proc. inter·noise 2004*, Prague (2004).

[11] Ohm, S.P. Lund, P.B. Poulsen and S. Jakobsen, '*Strategi for begrænsning af vejtrafikstøj – Delrapport 2. Støj, gener og sundhed*', Working Report No. 53 2003, Environmental Protection Agency, Copenhagen (2003).

[12] Damgaard, '*Hvad koster støj? – værdisætning af vejstøj ved brug af husprismetoden*', Environmental Project No. 795 2003, Environmental Protection Agency, Copenhagen (2003).

[13] Ohm and M. P. Jensen, '*Strategi for begrænsning af vejtrafikstøj – Delrapport 3. Virkemidler og samfundsøkonomiske beregninger*', Working Report No. 54, 2003, Environmental Protection Agency, Copenhagen (2003).

[14] H. Bentsen, L.E. Larsen and P. Greibe, '*Udvikling af støjreducerende vejbelægninger til bygader. Statusrapport efter 3 års målinger*', Report No. 4 2002, Danish Transport Research Institute (2002).

[15] L.E. Larsen and H. Bendtsen, 'Noise reduction with porous asphalt – costs and perceived effect', *Proc. 9th Int. Conf. on Asphalt Pavements 2002*, Copenhagen (2002).

[16] '*The DRI-DWW Noise Abatement Program - Project description*', Note No. 24, 2005, Danish Road Directorate – Danish Road Institute, Roskilde (2005).

[17] '*Noise Innovation Program. Road Traffic*', DWW report 2002-073, Road and Hydraulic Engineering Institute, Delft (2002).

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